BACKGROUND OF THE INVENTION

1.   Field of the Invention

The present invention generally relates to an image forming apparatus which forms an image on a surface of a photosensitive body through an optical scanning device, and, in particular, to an image forming apparatus by which, even employing a device having a low resolution, an apparatus having an apparently high resolution is provided.

2.   Description of the Related Art

Recently, improvement in resolution of an image forming apparatus has been demanded as in an LBP (laser beam printer) and so forth.

In order to render high resolution without increasing the printing speed of an LBP, ① the speed of rotation of a deflector such as a polygon scanner may be increased, ② the number of light sources may be increased and thereby scanning is rendered with a plurality of scan lines at once, or the like.

However, ① when the speed of rotation of a deflector such as a polygon scanner is increased, not only the polygon scanner itself becomes expensive, but also the durability thereof becomes degraded, the noise therefrom increases, the power consumption thereof

increases, and so forth.

Further, when ② the number of light sources is increased and thereby scanning is rendered with a plurality of scan lines at once, a configuration for composing a plurality of beams becomes complicated, the number of parts/components increases, thereby costs increasing, and assembling accuracy of the mounted parts/components cannot be maintained because of complexity of the device.

Further, improvement of resolution only in a main scan direction (the same as a deflection direction of a deflector) can be rendered by increasing a modulation frequency of a light source. However, by this method, it is not possible to improve resolution in a sub-scan direction.

As a method of solving the above-mentioned problems, and improving resolution in a main scan direction and also in a sub-scan direction, TrueRes technology is proposed in a document 'technology of improving resolution of page printer - TrueRes Interface Jan./Feb., 1996'. This method has also been put into practice.

The TrueRes technology is to utilize a characteristic in that a toner-adhering amount of toner adhering to a surface of a photosensitive body with

respect to an exposure time for which the photosensitive body is exposed by a beam is determined by an accumulation of the exposure time (exposure distribution).

5   FIG. 1 shows a characteristic of an exposure time and a toner-adhering amount.

In FIG. 1, in a range in that the exposure time 't' is not longer than t3 ($t \le t3$), a reaction critical value has not been exceeded, and the toner-

10   adhering amount TM is substantially zero.

In a range in that the exposure time falls between t3 and t4 ($t3 < t < t4$), the reaction critical value has been exceeded. Then, in a range in that the exposure time t is equal to or longer than t4 ($t \ge t4$),

15   the toner-adhering amount TM becomes TM0, and is saturated.

Because the toner-adhering amount is thus determined by accumulation of the exposure time, the toner-adhering amount becomes TM0 by four times of

20   exposure each rendered for the interval t1, and, this is the same as the toner-adhering amount rendered by once of exposure rendered for the interval t4.

Similarly, in a case where exposure is rendered for the interval t2, the toner-adhering amount

25   reaches TM0 by twice of the exposure.

FIG. 2 shows an image of improving resolution employing the TrueRes technology.

In FIG. 2, G11 through G13 represent dots formed on a scan line L1, G21 through G23 represent dots formed on a scan line L2, and, for each of them, exposure is rendered for an interval equal to or longer than t4 in the characteristic shown in FIG. 1, and, thereby, the toner-adhering amount is TM0.

Further, dots GA formed between adjacent dots can be formed through twice of exposure each rendered for the interval t2 in the characteristic shown in FIG. 1 on the positions of these adjacent dots, respectively.

For example, a new dot GA can be formed between the dots G11 and G12 on the main scan line L1 in the main scan direction, and another new dot GA can be formed between the dot G11 on the main scan line L1 and the dot G21 on the main scan line L2 in the sub-scan direction.

Thus, by employing the TrueRes technology, it is possible to improve resolution in the main scan direction and also in the sub-scan direction.

Further, in an image forming apparatus in the related art, as disclosed in Japanese Laid-Open Patent Application No. 10-250144 by the present applicant, by employing the TrueRes technology, employing a plurality

of LED (light emitting diode) arrays in a light source
thereof, configuring the respective LED arrays in the
main scan direction of a photosensitive body, and
controlling turning on/off of each diode, new dots are
formed between adjacent normal dots in the main scan
direction and in the sub-scan direction.

In the image forming apparatus disclosed in
Japanese Laid-Open Patent Application No. 10-250144, the
diameters of newly formed dots can be made to
approximate those of the normal dots.

In the image forming apparatus disclosed in
Japanese Laid-Open Patent Application No. 10-250144
employing the TrueRes technology, resolution of newly
formed dots is determined by exposure distribution, and,
also, the exposure distribution is mainly determined by
a static beam-spot diameter and intervals between scan
lines in the sub-scan direction. Accordingly, the
resolution is not improved unless the static beam-spot
diameter and intervals between scan lines in the sub-
scan direction are properly set.

SUMMARY OF THE INVENTION

The present invention has been devised in
order to solve such a problem, and an object of the
present invention is to provide an image forming

apparatus in which the static beam-spot diameter and intervals between scan lines in the sub-scan direction are properly set, and, thereby, resolution in the sub-scan direction is improved.

5   Another object of the present invention is to set a condition of improving resolution in the main scan direction.

According to the present invention,

a dot is formed at a center between adjacent

10   light fluxes as a result of the adjacent light fluxes being overlapped with one another in a sub-scan direction, and

a ratio of a static beam-spot diameter Ws in the sub-scan direction on the surface of a

15   photosensitive body defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot (the diameter of the area of the beam spot through which the exposure intensity is not lower than $1/e^2$ of the maximum value thereof, also hereinafter) to an interval L (in a

20   center-to-center basis, also hereinafter) between adjacent scan lines satisfies the following formula:

$$1.2 < Ws / L < 4.5$$

25   Thereby, it is possible to easily form a dot

at the center between adjacent scan lines, to render

shortening of a diameter of each dot and stabilization

of the dots and to increase resolution in the sub-scan

direction. Accordingly, it is possible to form high-

5   resolution images.

Further, a ratio of a static beam-spot

diameter Wm in a main scan direction on the surface of

the photosensitive body defined by $1/e^2$ of the maximum

value in the exposure distribution of the beam spot to

10   the static beam-spot diameter Ws in the sub-scan

direction on the surface of the photosensitive body

defined by $1/e^2$ of the maximum value in the exposure

distribution of the beam spot satisfies the following

formula:

15

     Wm / Ws < 1

Thereby, it is possible to increase resolution

in the main scan direction, and to form high-resolution

20   images also high in resolution in the main scan

direction.

Other objects and further features of the

present invention will become more apparent from the

following detailed description when read in conjunction

25   with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a characteristic between exposure time and toner-adhering amount;

FIG. 2 shows an image of increasing resolution by using TrueRes technology;

FIGS. 3A and 3B show a general configuration of an image forming apparatus in each of first through tenth embodiments of the present invention;

FIG. 4 shows an image of forming a new dot for increasing resolution in a sub-scan direction according to the present invention;

FIG. 5 shows conditions of a comparison example and the first through tenth embodiments of the present invention;

FIG. 6 shows a perspective view (bird's-eye view) of exposure distribution in the comparison example;

FIG. 7 shows a perspective view (bird's-eye view) of exposure distribution in the first embodiment of the present invention;

FIG. 8 shows a perspective view (bird's-eye view) of exposure distribution in the second embodiment of the present invention;

FIG. 9 shows a perspective view (bird's-eye view) of exposure distribution in the third embodiment

of the present invention;

FIG. 10 shows a perspective view (bird's-eye view) of exposure distribution in the fourth embodiment of the present invention;

5 FIG. 11 shows a perspective view (bird's-eye view) of exposure distribution in the fifth embodiment of the present invention;

FIG. 12 shows a perspective view (bird's-eye view) of exposure distribution in the sixth embodiment 10 of the present invention;

FIG. 13 shows a perspective view (bird's-eye view) of exposure distribution in the seventh embodiment of the present invention;

FIG. 14 shows a perspective view (bird's-eye 15 view) of exposure distribution in the eighth embodiment of the present invention;

FIG. 15 shows a perspective view (bird's-eye view) of exposure distribution in the ninth embodiment of the present invention;

20 FIG. 16 shows a perspective view (bird's-eye view) of exposure distribution in the tenth embodiment of the present invention;

FIG. 17 shows an exposure distribution of the comparison exmaple on a section parallel to a sub-scan 25 direction and passing through a point at which the

exposure distribution has the maximum value;

FIG. 18 shows an exposure distribution of the first embodiment of the present invention on a section parallel to the sub-scan direction and passing through a

5   point at which the exposure distribution has the maximum value;

FIG. 19 shows an exposure distribution of the second embodiment of the present invention on a section parallel to the sub-scan direction and passing through a

10   point at which the exposure distribution has the maximum value;

FIG. 20 shows an exposure distribution of the third embodiment of the present invention on a section parallel to the sub-scan direction and passing through a

15   point at which the exposure distribution has the maximum value;

FIG. 21 shows an exposure distribution of the fourth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a

20   point at which the exposure distribution has the maximum value;

FIG. 22 shows an exposure distribution of the fifth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a

25   point at which the exposure distribution has the maximum

value;

FIG. 23 shows an exposure distribution of the sixth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a
5   point at which the exposure distribution has the maximum value;

FIG. 24 shows an exposure distribution of the seventh embodiment of the present invention on a section parallel to the sub-scan direction and passing through a
10   point at which the exposure distribution has the maximum value;

FIG. 25 shows an exposure distribution of the eighth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a
15   point at which the exposure distribution has the maximum value;

FIG. 26 shows an exposure distribution of the ninth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a
20   point at which the exposure distribution has the maximum value; and

FIG. 27 shows an exposure distribution of the tenth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a
25   point at which the exposure distribution has the maximum

value.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 3A and 3B show a general configuration

5   of an image forming apparatus in each embodiment of the

present invention.

In FIG. 3A, the image forming apparatus 1

includes a control part 2 having a microprocessor as a

base and a memory, and having an operation function and

10   a processing function, and controlling operation of the

entirety of the apparatus, a driving part 3 driving an

optical scanning device 4 based on a control signal and

an image signal provided by the control part 2, the

optical scanning device 4 having a laser diode 4A, a

15   polygon mirror 4B and so fourth, and scanning a

photosensitive body 6 having a photosensitive layer in a

main scan direction thereof by a laser beam reflected by

the polygon mirror 4B, and an image process part 5

provided in a paper passage 13 communicating a paper

20   feeding device 12 containing transfer paper 11, which is

recording media, with a paper ejecting part not shown in

the figure.

The image process part 5 includes the

photosensitive body 6 having a configuration of a

25   photosensitive dram as a main part, and, a charging

device 7, a developing device 8, a transfer device 9 and a cleaning device 10 arranged around the photosensitive body 6.

The charging device 7 charges a surface of the photosensitive body 6 to one polarity (for example, a minus (-) polarity) uniformly through charging by a roller charging method.

When the optical scanning device 4 applies a laser beam to the photosensitive body 6, an electrostatic latent image (beam spot) is formed at a portion at which the laser beam is applied to. When the laser beam is deflected as the polygon mirror 4B rotates, shown in FIG. 3B, the electrostatic latent image is formed in the main scan direction of the photosensitive body 6.

The developing device 8 causes toner having an electric-potential difference with respect to the electrostatic latent image to adhere to the electrostatic latent image formed on the photosensitive body 6. Thereby, the electrostatic latent image is visualized.

The transfer device 9 attracts the thus-visualized toner image from the photosensitive body 6 by an electric-potential difference, and transfers the toner image onto the transfer paper 11.

The cleaning device 10 removes the toner remaining on the photosensitive body 6 after the transfer, by a method of scraping or the like, and, thus, cleans the photosensitive body 6.

5   A fixing device 14 is disposed on the downstream side of the transfer device 9 in the paper passage 13, heats and presses the un-fixed toner adhering to the transfer paper 11 having passed through the transfer device 9, and ,thus, fixes the toner onto

10   the transfer paper 11.

The control part 2 modulates an image signal through the driving part 3, controls light-emitting intensity or light-emitting time of the laser beam like a pulse according to resolution (for example, 600 dpi.

15   1200 dpi, or the like) of the apparatus emitted from the laser diode 4A, and controls the rotation of the polygon mirror 4B.

Further, the control part 2 controls the rotation of the drum of the photosensitive body 6, and,

20   when scanning one scan line the surface of the photosensitive body 6 is finished, rotates the drum for a scan-line interval L, so that the laser beam scans a subsequent scan line.

Further, the control part 2 controls operation

25   and timing of the charging device 7, developing device 8,

transfer device 9 and cleaning device 10 of the image

process part 5 other than the photosensitive body 6.

FIG. 4 shows an image of forming new dots for

improving resolution in the sub-scan direction.

5   When beam spots are formed at the scan-line

interval L, the resolution in the sub-scan direction is

1/L (dpi). However, by forming a dot at a position at

which beam spots 15 and 16 overlap with one another, it

is possible to improve the resolution in the sub-scan

10   direction.

In FIG. 4, the beam spot 15 is a beam spot

formed on a main scan line 1 and the beam spot 16 is a

beam spot formed on a main scan line 2.

The new dot 17 (hatched in the figure) is

15   formed at the position at which the beam spots 15 and 16

overlap with one another in the sub-scan direction

between the main scan line 1 and main scan line 2.

However, unless the static beam-spot diameter

and interval between scan lines in the sub-scan

20   direction are properly set, not only the resolution is

not improved, but also it is not possible to reproduce

image information precisely, and it may even result in

degradation in image quality.

A condition for improving the resolution in

25   the sub-scan direction without degrading the image

quality is that a ratio of the static beam-spot diameter Ws in the sub-scan direction on the surface of the photosensitive body defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot to the

5   interval L between adjacent scan lines in the sub-scan direction is set so that the following formula (1) is satisfied:

$$1.2 < Ws / L < 4.5 \qquad \cdots (1)$$

10

When the ratio Ws / L in the above formula (1) is not larger than the lower limit 1.2, no new dot is formed at a center between the two adjacent scan lines in overlapped exposure distributions of the two beam

15   spots, but two dots separate in the sub-scan direction are newly formed.

When Ws / L in the above formula (1) is not smaller than the upper limit 4.5, the diameter of the static beam spot is too large with respect to the scan-

20   line interval L, and the new dot is too large and/or is unstable.   Thereby, it is not possible to render high resolution.

Further, in order to make resolution equal between the main scan direction and sub-scan direction,

25   beam spots apart by the half of the scan-line interval

(L/2) in a center-to-center basis are made separate as far as possible for the main scan direction while the part at which two beam spots with the scan-line interval L overlap with one another is utilized for the sub-scan direction.

At this time, it is necessary that the ratio of the static beam-spot diameter Wm in the main scan direction defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot on the surface of the photosensitive body to the static beam-spot diameter Ws in the sub-scan direction defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot on the surface of the photosensitive body satisfies the following formula (2):

$$Wm / Ws < 1 \qquad \cdots \quad (2)$$

When Wm / Ws in the formula (2) is not smaller than the upper limit 1, the beam-spot diameter Wm in the main scan direction is too large with respect to the dot interval in the main scan direction, and, thereby, dots are thickened, and/or, unstable. Accordingly, it is not possible to render high resolution.

Reasons why the above-mentioned formulas (1) and (2) are reasonable will now be described based on a

comparison example and the embodiments of the present
invention.

FIG. 5 shows conditions of the comparison
example and embodiments of the present invention.

5   In each of the comparison exmaple and
embodiments 1 through 10, a new dot formed in the sub-
scan direction is formed from overlapping, with one
another, two beam spots on main scan lines adjacent in
the sub-scan direction with the scan-line interval of L.

10   Further, the beam spot moves in the main scan
direction while the light source (laser light) is turned
on, and each moving distance is assumed to be 1/4 of the
scan-line interval L (L/4).

Further, the shape of a static beam spot is

15 assumed to be of an ideal Gaussian distribution.

Further, each of Wm and Ws is a diameter of a
beam spot in a stationary state defined by $1/e^2$ of the
maximum value in the exposure distribution of the beam
spot.

20   FIGS. 6 through 16 show perspective views of
the exposure distributions in intensity of the
comparison exmaple and 1 through 10 embodiments of the
present invention, and FIGS. 17 through 27 show the
exposure distributions in intensity each on a section

25 passing through the point at which the exposure

distribution has the maximum value in intensity and in parallel to the sub-scan direction.

In each figure, the intensity of exposure distribution is normalized so that the maximum value is 5 100, and, it is assumed that, when the exposure intensity exceeds 50% of the maximum value, a new dot is formed there.

In the comparison example shown in FIGS. 6 and 17, two dots are separate, and the exposure intensity at 10 the center between adjacent scan lines is far smaller than 50% of the maximum value. Accordingly, no new dot cannot be formed there.

In this comparison exmaple, Ws / L = 1, and, thus, the condition of the formula (1) is not satisfied.

15 In each of the embodiment 1 shown in FIGS. 7 and 18, and the embodiment 6 shown in FIGS. 12 and 23, there is no peak at the center between adjacent scan lines. However, the exposure intensity at the center exceeds 50% of the maximum value. Accordingly, a new 20 dot can be formed at the center.

In each of the embodiments 1 and 6, Ws / L = 1.21. Thus, this value is very near to the lower limit 1 of the formula (1).

As described above, when the exposure 25 intensity exceeds 50% of the maximum value at the center

between adjacent scan lines, a new dot can easily be formed at the center between the adjacent scan lines, and, Ws / L is equal to the lower limit value 1 when the exposure intensity at the center of the adjacent scan

5 lines is 50% of the maximum value.

In each of the embodiment 5 shown in FIGS. 11 and 22 and the embodiment 7 shown in FIGS. 13 and 24, Ws / L = 1.40, and there is no peak at the center between adjacent scan lines. However, the exposure intensity at

10 the center exceeds 50% of the maximum value, and, also, is higher than those in the embodiments 1 and 6. Accordingly, a new dot can be formed at the center more positively.

In each of the embodiment 2 shown in FIGS. 8

15 and 19 and the embodiment 8 shown in FIGS. 14 and 25, Ws / L = 1.81. Accordingly, a new dot can be formed at the center between adjacent scan lines far more positively.

In each of the embodiment 3 shown in FIGS. 9 and 20, the embodiment 4 shown in FIGS. 10 and 21, the

20 embodiment 9 shown in FIGS. 15 and 26 and the embodiment 10 shown in FIGS. 16 and 27, 2.5 < Ws / L < 4.5. Accordingly, the exposure distribution has a peak at the center between adjacent scan lines. Accordingly, a new dot can be formed at the center between adjacent scan

25 lines easily.

However, when Ws / L becomes equal to or higher than the upper limit (4.5) of the formula (1), the static beam-spot diameter in the sub-scan direction with respect to the scan-line interval L is too large,

5   and, thereby, the new dot is too large, and/or is unstable. Accordingly, it is not possible to render high resolution.

When considering to render formation of a dot at the center between adjacent two scan lines and

10   shortening of diameter of each image dot and stability of the image dots, it is preferable that the ratio of the static beam-spot diameter Ws in the sub-scan direction on the surface of the photosensitive body defined by $1/e^2$ of the maximum value in the exposure

15   distribution of the beam spot to the scan-line interval L satisfies the following formula (3):

$$1.8 < Ws / L < 3.5 \qquad \cdots \quad (3)$$

20   Further, as shown in FIG. 5, each of the embodiments 1 through 10 satisfies the condition of the above-mentioned formula (2), and it is possible to render high resolution also in the main scan direction. However, it is preferable that the ratio of Wm to Ws

25   satisfies the following formula:

Wm / Ws < 0.85

Although the light source used in each of the embodiments of the present invention is of a single
5   light source, it is also possible that the light source is of a combination of a plurality of light sources is employed instead.

Further, although the light source used in each of the embodiments of the present invention is a
10 laser light source, it is also possible that the light source includes a plurality of LEDs (Light Emitting Diodes) disclosed in Japanese Laid-Open Patent Application No. 10-250144.

Furthermore, although the static beam-spot
15 shape in each embodiment is assumed to be of an ideal Gaussian distribution, it is also possible that it is slightly different from a shape of an ideal Gaussian distribution.

The present invention is not limited to the
20 above-described embodiments, and variations and modifications may be made without departing from the scope of the present invention.

The present application is based on Japanese priority application No. 2000-026780 filed on February 3,
25 2000, the entire contents of which are hereby

incorporated by reference.